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ROBOT SIMULATOR

TECHNICAL FIELD

The invention presented here concerns a method and a device for simulating an aircraft missile during testing of an aircraft system that includes a weapons system for controlling the missile.

STATE OF THE ART

Modern aircraft comprise flying-control systems that include computers, electronics and software for monitoring and controlling the functions of the aircraft. This system, referred to here as the aircraft system, in military aircraft includes a weapons system whose purpose is to monitor and operate the various functions of the aircraft's weapons. Included in the said functions of the weapons is control of missiles with which the aircraft may be equipped. Such missiles may be fitted with a target seeker, which can take up a specific position, directed for example at a target. Guidance of the target seeker towards the target is accomplished by means of a signal from the weapons system.

The target seeker in the missile is controlled by a control loop, which as is usual comprises a trouble signal, in this case from the weapons system to the target seeker, and an actual value signal containing an actual value describing the actual position of the target seeker. In practice, control is commonly effected by coils fitted to the trouble signal, which controls a magnetic freely-suspended gyro, which in turn causes the target seeker to rotate itself to the guided position. The actual value signal is created by means of a purpose designed fixed coil which detects the gyro's position and sends the information via the actual value signal. The actual value signal is a sinusoidal shaped signal the amplitude of which describes the target seeker's torsional angle and whose phase position relative to a reference signal describes the direction in which the gyro and the target seeker are rotated.

During testing of aircraft systems as described above it common to use a missile of the type in question and connect this to a specially designed gun carriage on the aircraft. The missile has in such cases been disengaged from its drive motor and its explosive components, i.e. the active weaponery.

Naturally, it is impractical to have to handle missiles in this manner in order to be able to perform a test of the system and all its functions.

A known method for simulating a missile involves taking a discrete measurement of the command signal from the weapons system to the missile, imitating the operations of the missile and sending back a simulated actual value signal to the weapons system. A difficulty with such a simplified simulation is to be able to measure the command signal and interpret it in the same way as the missile would.

DESCRIPTION OF THE INVENTION

One aspect of the invention consists of a method specified in the independent claim 1.

Simulation of a missile according to the aspect of the invention permits continuous measurement of the command signal in the aircraft system.

The principles of simulation of the missile can be summarized as follows:
A signal with the command position for the missile's target seeker is received by a summing unit in the aircraft's weapons system. In addition, the signal for the actual position of the target seeker in the missile is received by the said summing unit. A trouble signal equivalent to the deviation between the command position and the actual position is obtained as an output signal from the summing unit. The trouble signal is used as a control signal for the target seeker.

During missile simulation the trouble signal first passes a hardware interface which adapts the trouble signal to a computer model for the missile's target seeker. The error in amplitude and angle of the vector which specifies the direction to the target is sent from the interface to the computer model. The behaviour of the actual missile is simulated in the computer model, whereupon a simulated actual value of amplitude and angle of the position of the target seeker is sent back to the interface, where an actual value signal adapted to the weapons system is created. The said actual value signal is inverted so as to give a negative contribution when the actual value signal is added in the said summing unit.

During simulation there are time-continuous signals before the interface and time-discrete signals after the interface, where these signals are fed to the computer model. The actual missile operates only with time-continuous signals. The time-discrete signals are obtained by a sampling of the input time-continuous signals. It is important here that the signals at the moment of sampling as closely as possible assume the values that they would in the actual time-continuous system at corresponding points in time and that noise and interference are suppressed.

The actual position (actual value) of the target seeker can be simply recorded using the method presented here, since the actual value is produced by a computer. When using a real missile in the test the actual value must be measured instead. This is unnecessary, since it is precisely this measurement in the weapons system that is, for example, verified by the aspect of the invention.

DESCRIPTION OF FIGURES

Figure 1 shows schematically the principles for construction of the equipment used in simulating a missile according to the aspect of the invention.

Figures 2a and 2b illustrate how the target seeker's position is represented graphically.

EMBODIMENTS OF THE INVENTION

A number of examples of the described aspect of the invention are described below with the aid of the figures.

Figure 1 shows a block representing the weapons system 1 of the aircraft. This includes a summing unit 2, which receives a command signal 3 indicating the position for the target. The summing unit 2 also receives an actual value signal 4 from the missile model 5, which simulates the operation of the missile during target guidance. Since the actual value signal 4 produces a negative contribution to the summing unit 2 there will be a difference between the

command position and the actual position of the missile simulator's target seeker, where this difference is used as a trouble signal 6 for the missile model 5. The previously mentioned hardware interface is represented by block 7 in the figure. The trouble signal 6 to the interface 7 is a continuous signal, which is sampled in the interface 7 and provides sample values for the deviation ΔA in the amplitude and for the deviation $\Delta\varphi$ in the phase angle. These two values are time-discrete values. The actual values for the position of the simulated target seeker is sent from the missile model 5 back to the interface 7 in the form of amplitude A and phase angle φ. These values are converted in the interface 7 to the said time-continuous actual value signal 4, which is returned to the weapons system's 1 summing unit 2. A reference signal 8 is also sent from the interface 7 to the weapons system 1.

The different signals are given by:

actual position: $S = A\sin(\omega t + \varphi)$

commanded position: $S^c = A^c \sin(\omega t + \varphi^c) = (A + \Delta A) \sin(\omega t + \varphi + \Delta\varphi)$

reference signal: $A^r \sin(\omega t)$

trouble signal: $\Delta = Sc - S$ predicted p radians, that is

$$\Delta = A^c \sin(\omega t + \varphi^c + p) - A \sin(\omega t + \varphi + p)$$

By measuring the trouble signal 6 in the interface 7 and by exploiting the fact that the actual value is known, ΔA and $\Delta\varphi$ are determined as closely as possible. This can be done in different ways. The simplest way is to measure Δ at two points in time, for example when the signal S is at its maximum and when the signal S passes through zero on a certain flank and then from these two determined relationships work out ΔA and $\Delta\varphi$. Another way is to use a measuring method involving generation of a mean. How the correlation method is used is described below.

From the trouble signal 6 two new signals are produced as follows

$\Delta\sin = \Delta \times \sin(\omega t + \varphi)$

$\Delta\cos = \Delta \times \cos(\omega t + \varphi)$

both functions of which are integrated giving the integrals

$$I_1 = \int_0^{2\pi/\omega} \Delta \sin dt \qquad \text{and} \qquad I_2 = \int_0^{2\pi/\omega} \Delta \cos dt$$

From I_1 and I_2, ΔA and $\Delta\varphi$ can then be solved.

By derivation one gets

$$\Delta\varphi = \begin{cases} a\tan 2(T,N) - p & \text{if} \quad (T)^2 + (N)^2 > k \\ 0.0 & \text{otherwise} \end{cases},$$

where $T = \omega I_2 + \pi A \sin p$ and $N = \omega I_1 + \pi A \cos p$

and

$$\Delta A = \begin{cases} \dfrac{\omega I_1 + \pi A \cos p}{\pi \cos(\Delta\varphi + p)} - A & \text{if} \quad |\sin(\Delta\varphi + p)| < 0.5 \\ \dfrac{\omega I_2 + \pi A \sin p}{\pi \sin(\Delta\varphi + p)} - A & \text{otherwise} \end{cases}$$

In practice a numerical method can be employed to calculate the integrals. In the method according to the invention an approximation using sums is used in the interface 7. The summation in the example is performed at 512 points evenly spread out over the period of time. Such an approximation gives satisfactorily good results. Since the integration is performed over the whole period of the signal it takes a certain amount of time from the moment the input signal enters the interface 7 until the output signal from the interface 7 becomes available. One result of this is that there is a delay of one sample period during simulation of the position of the target seeker.

Naturally, mathematical methods other than the above correlation method can be used. The described correlation method has, however, been shown to work very well. In particular, this method has proved favourable since it avoids the problem of sensitiveness to interference.

By using the shown correlation method it has been established how the target seeker's actual position differs from the commanded one. What remains to be done is to analyse how the target seeker responds to the error and to simulate this. Fig. 2a shows the definition of the target seeker's position vector S in a three-dimensional coordinate system, with the x-axis

pointing straight ahead in relation to the aircraft, where the angle λ shows the angle of the position vector in relation to the x-axis, and δ shows the angle of the position vector in relation to the y-axis, with the position vector projected onto the yz-plane. In figure 2b, the actual position of the target seeker is indicated by the vector S_0 and its commanded position by S^c. The angle between these vectors η_0 can be called the angle of error and this is to be minimised.

A mathematical treatment of these vectors results in the equation

$$\overline{S_0} = \begin{pmatrix} x_0 \\ y_0 \\ z_0 \end{pmatrix} = \begin{pmatrix} \cos A_0 \\ \sin A_0 \cos \varphi_0 \\ \sin A_0 \sin \varphi_0 \end{pmatrix} \quad \text{and} \quad \overline{S_C} = \begin{pmatrix} x^C \\ y^C \\ z^C \end{pmatrix} = \begin{pmatrix} \cos A^C \\ \sin A^C \cos \varphi^C \\ \sin A^C \sin \varphi^C \end{pmatrix}$$

The size of the error is given by

$$d = \left| S^C - S_0 \right| = \sqrt{(x^C - x_0)^2 + (y^C - y_0)^2 + (z^C - z_0)^2}$$

which is then recalculated to an angle of error

$$\eta_0 = 2\operatorname{asin}\frac{d}{2}.$$

During a sample period the angle of error changes to

$$\eta = \eta_0 e^{-25\times 0.02} \quad \text{if } \eta_0 \le 1^\circ \text{, or to}$$

$$\eta = \eta_0 - 25 \cdot 0.02 \frac{\pi}{180} \quad \text{if } \eta_0 > 1^\circ.$$

The new actual position will be

$$\overline{S} = \overline{S_0} + \frac{\sin(\eta_0 - \eta)}{\sin(\pi/2 + \eta - \eta_0/2)} \cdot \frac{\overline{S^C} - \overline{S_0}}{d} \quad \text{if } \eta_0 > 1^\circ \text{, or}$$

$$\overline{S} = \overline{S_0} + (1 - e^{-25\times 0.02})(\overline{S^C} - \overline{S_0}) \quad \text{if } \eta_0 \le 1^\circ$$

This vector is extended so that a unit vector is obtained

$$\bar{S} = \frac{\bar{S}}{|\bar{S}|}$$

Subseauently the conversion to polar coordinates is made again

$$A = a\tan 2(\sqrt{y^2 + z^2}, x)$$
$$\varphi = a\tan 2(z, y)$$

When the target seeker positions itself it does so in such a way that S_0 moves in a plane toward S^c, i.e. the point of the vector follows the course of a large circle. The target seeker is, however, unable to move at unlimited speeds, but takes a certain amount of time in order to position itself. There are two conditions regarding the target seeker's movement; one is that the movement shall be in one plane, the other is that the speed is limited. These circumstances are taken into account in the derivation of the relationship above.